

Serial No.: 09/991,761

Docket No.: PHUS017060US (PII 3340)

Amendment A

**Remarks**Claims

Claims 1-20 are pending in the application.

Claims 1-9 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Molyneaux *et al.* (US 5,578,925) in view of Oppelt (US 5,128,615) and further in view of Mehdizadeh *et al.* (US 4,918,388).

Claims 10-13 stand rejected under 35 U.S.C. 102(b) as being anticipated by Oppelt *et al.* (US 5,153,517).

Claim 14 stands rejected under 35 U.S.C. 103(a) as being unpatentable over Oppelt (US 5,153,517) and further in view of Mehdizadeh *et al.* (US 4,918,388).

Claims 15-20 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Oppelt (US 5,153,517) and further in view of Mehdizadeh *et al.* (US 4,918,388).

Claim 10 has been amended. Claim 14 has been cancelled. Claims 1-9, 11-13, and 15-20 remain in the application unamended.

**THE OPPELT '517 REFERENCE**

Oppelt '517 is directed to a magnetic resonance imaging apparatus which includes a fundamental field magnet 2, for example, a C-magnet, having a shape so that the static, fundamental magnetic field  $B_{sub.0}$  generated thereby proceeds parallel to the z-axis of a rectangular coordinate system. The apparatus can be used to generate tomograms of parts of a human body whose body axis extends along the x-axis of the coordinate system. See Oppelt '517, column 3, lines 56-64.

Oppelt '517 further teaches a circularly polarizing surface resonator 10 between the pole pieces 3 and 4 of the C-magnet. The resonator 10 produces a magnetic field  $B_{sub.11}$  which proceeds approximately parallel to the resonator plane 6 in the examination region 8.

With respect to the resonator, Oppelt teaches that the resonator 10 is formed by sub-systems 11 and 12 shown respectively in FIGS. 2 and 3. See Oppelt '517, column 4, lines 13-15. The resonant current  $I_{sub.11}$  produces a magnetic field  $B_{sub.11}$ , whose course is rotated by 90 degrees relative to the magnetic field  $B_{sub.12}$  of the sub-system 12. See Oppelt '517, column 4, lines 45-49.

As for the construction of the resonator, Oppelt teaches that a preferred embodiment (See Fig. 4) of the surface resonator 10 is formed by a combination of

Serial No.: 09/991,761

Amendment A

Docket No.: PHUS017060US (PII 3340)

the two sub-systems 11 and 12 of FIGS. 2 and 3. The two sub-systems 11 and 12 are placed on top of one another so as to be substantially arranged in the same plane, perpendicular to the fundamental magnetic field  $B_{sub.0}$ . See, Oppelt '517, column 4, lines 50 - column 4, line 55. Oppelt describes this preferred embodiment as being in the form of a spoked wheel. See Oppelt, column 4, lines 55-60.

#### THE MEHDIZADEH REFERENCE

Mehdizadeh *et al.* teaches that a localized coil *D* includes a first thin, preferably planar coil 30 which in a transmit mode would generate a magnetic field along a first axis and in a reception mode would be most receptive to magnetic field components along the first axis. In the illustrated embodiment, the first coil is rectangular or loop coil that is oriented to generate or receive fields along the y-axis. A second thin, preferably planar coil 32 transmits magnetic fields along and receives magnetic fields from a second axis different from the first axis. In the preferred embodiment, the second coil generates magnetic fields along and receives magnetic resonance signals from along an x-axis. See Mehdizadeh, column 3, lines 49-

With reference to FIG. 3, Mehdizadeh *et al.* teaches that the first and second coils are generally coplanar and lie on opposite faces of an insulator, e.g. etched in opposite faces of a dual faced circuit board 36. See Mehdizadeh, column 3, line 66 - column 4, line 3.

With reference to FIG. 1, Mehdizadeh *et al.* discloses that the magnetic resonance imaging apparatus used in conjunction with the planar coil 32 includes a main magnetic field means *A* for establishing a generally static, main magnetic field longitudinally through an image region along a z-axis, i.e. in a direction generally parallel to the plane of the planar coil. See Mehdizadeh *et al.*, column 3, lines 9-12.

#### THE MOLYNEAUX REFERENCE

With reference to FIG. 1, Molyneaux *et al.* discloses an imaging region 10 defined between pole pieces 12, 14. For imaging, magnetic field gradient coils 20, 22 are disposed at the pole pieces 12, 14. In order to excite magnetic resonance in dipoles of a subject disposed in the examination region 10, radio frequency coils 30, 32 are disposed between the gradient coils and the imaging region. See Molyneaux *et al.* column 4, lines 14-39.

Serial No.: 09/991,761  
Docket No.: PHUS017060US (PII 3340)

Amendment A

With respect to receive coils, Molyneaux *et al.* discloses a radio frequency surface coil assembly 50 disposed along a region of interest of the subject. In the embodiment of FIG. 1, the surface coil assembly 50 is an elongated spine coil that is disposed on a patient supporting surface immediately below the spinal column of a patient resting on the patient supporting surface. As is explained in conjunction with FIGS. 3 and 4, the surface coil assembly 50 is an array of coils, each connected with one or more receivers 52. *See Molyneaux et al.* column 4, lines 50-66.

With reference to FIG. 2, the coil array 50 has a plurality of window pane coils 50.sub.1, 50.sub.2, etc. of like construction. Each of the window pane coils has two modes, one in the x-direction and one in the z-direction. For a two-coil construction, Molyneaux *et al.* teach that there are thus four modes--two x-modes and two z-modes. The x-modes and z-modes within each coil are orthogonal to each other and have minimum mutual inductance due to the symmetry. Molyneaux *et al.* further teach that the coils are overlapped such that the x-modes between two adjacent coils have a minimum mutual inductance due to spatial position. Preferably, the z-modes of the two coils also have minimum mutual inductance at the overlap. *See Molyneaux et al.*, column 5, lines 8-52.

#### THE OPPELT '615 REFERENCE

Oppelt '615 discloses a magnetic resonance imaging apparatus shown in FIG. 1, with a resonator constructed as generally shown at 10. The apparatus includes a magnet 2, for example a C-magnet, which generates a static, fundamental magnetic field  $B_{sub.0}$  proceeding parallel to the z-axis of a rectangular coordinate system having x, y and z axes. In this embodiment Oppelt '615 teaches that the resonator 10 generates magnetic fields  $B_{sub.11}$  and  $B_{sub.12}$  (see FIG. 2). The magnetic field  $B_{sub.11}$  proceeds approximately parallel to the x-y plane in the region 8. *See Oppelt et al.* '615, column 3, line 50 - column 4, line 7.

#### THE PRESENT APPLICATION

The present invention provides a radio frequency coil that provides quadrature reception/transmission in vertical  $B_0$  field magnets.

In accordance with one aspect of the present invention a magnetic resonance imaging apparatus is provided. The magnetic resonance imaging apparatus includes a

Serial No.: 09/991,761

Docket No.: PHUS017060US (PII 3340)

Amendment A

main magnet assembly for generating a main magnetic field in a main magnetic field direction in an examination region, a gradient coil assembly for generating magnetic gradient fields in the main magnetic field within the examination region, a radio frequency transmit coil assembly for exciting resonance in selected dipoles within a subject disposed in the examination region such that the dipoles generate circularly polarized resonance signals at a characteristic resonance frequency, a radio frequency receive coil assembly for receiving the circularly polarized resonance signals generated by the dipoles, and a reconstruction processor for reconstructing the received signals into an image representation. The radio frequency receive coil assembly is disposed in the examination region substantially perpendicular to the main magnetic field direction and includes a substantially planar substrate and an array of quadrature coils disposed on the substrate. Each quadrature coil includes a first loop portion disposed on a first surface of the substrate and a second loop portion disposed on a second surface of the substrate.

One advantage of the present invention is that it provides a quadrature radio frequency receive coil that is substantially planar in a direction perpendicular to the main magnetic field of a magnetic resonance imaging system.

Another advantage of the present invention is that it provides a radio frequency coil that is oriented in a plane which is perpendicular to the main field of an open magnet and receives circularly polarized signals oriented in that plane.

Another advantage of the present invention is that the radio frequency coil is useful in phased array applications.

**THE CLAIMS DISTINGUISH PATENTABLY AND UNOBVIOUSLY  
OVER THE REFERENCES OF RECORD**

*The 102 Rejection*

**Claim 10**, as amended, is directed to a method of magnetic resonance imaging comprising: generating a main magnetic field in a main direction in an examination region; generating magnetic field gradients in the main magnetic field; transmitting radio frequency signals into the examination region to excite selected dipoles in a subject disposed in the examination region such that the dipoles are circularly polarized in a plane perpendicular to the main direction; and receiving circularly polarized radio frequency signals from the excited dipoles using a receive coil

Serial No.: 09/991,761

Docket No.: PHUS017060US (PII 3340)

Amendment A

assembly, the receive coil assembly comprising an array of quadrature coils, each quadrature coil for receiving the radio frequency signals from the circularly polarized dipoles and comprising a first loop portion disposed on a first side of a substrate and a second loop portion disposed on a second side of a substrate, opposite the first side, such that there is substantially no mutual inductance between adjacent quadrature coils of the array.

Claim 10 has been amended to include the limitations of claim 14 as originally filed. Accordingly, Applicant respectfully requests for the rejection under section 102 to be withdrawn.

With respect to claim 14, the Office Action states that claim 14 stands rejected under section 103(a) as being unpatentable over Oppelt '517 in view of Mehdizadeh *et al.* The conclusion reached in the Office Action that it would have been obvious to one of ordinary skill in the art to adapt Mehdizadeh *et al.*'s coils on a substrate with the magnetic resonance imaging apparatus of Oppelt to improve sensitivity of the coils, and to increase comfort to the patient during imaging is not supported.

First, the Office Action has not set forth how such a combination would improve sensitivity. Second, the Office Action has not set forth how an increase in comfort would be achieved. Finally, the Office Action has not set forth how such a combination would be made. As set forth above, Oppelt '517 teaches a coil in the form of a spoked wheel. The Office Action has not set forth how this arrangement could be made on first and second sides of a substrate as set forth in amended claim 10.

In light of the foregoing, Applicant respectfully asserts that claim 10 is patentable over the prior art of record.

Claims 11-13 depend from claim 10. For at least the reasons set forth above in connection with claim 10, Applicant respectfully asserts that claims 11-13 are patentable over the prior art of record.

#### *The 103 Rejections.*

Claim 1, is directed to a magnetic resonance imaging apparatus comprising, in part, a radio frequency receive coil assembly for receiving the circularly polarized resonance signals generated by the dipoles, the radio frequency receive coil assembly being disposed in the examination region substantially perpendicular to the main

Serial No.: 09/991,761

Docket No.: PHUS017060US (PII 3340)

Amendment A

magnetic field direction and comprising a substantially planar substrate; and an array of quadrature coils disposed on the substrate, each quadrature coil comprising a first loop portion disposed on a first surface of the substrate and a second loop portion disposed on a second surface of the substrate.

**Claims 1-9** stand rejected under 35 U.S.C. 103(a) as being unpatentable over Molyneaux *et al.* (US 5,578,925) in view of Oppelt (US 5,128,615) and further in view of Mehdizadeh *et al.* (US 4,918,388).

Applicant respectfully asserts that there is no suggestion or motivation to combine these references. Further, as set forth above in connection with claim 10, Applicant respectfully asserts that the increase in sensitivity and patient comfort set forth in the Office Action is not supported. Further, the Office Action has not set forth how such a combination of these references would be made.

**Claims 15-20** stand rejected under 35 U.S.C. 103(a) as being unpatentable over Oppelt (US 5,153,517) and further in view of Mehdizadeh *et al.* (US 4,918,388).

Again, the assertion in the Office Action that such a combination would improve coil sensitivity and patient comfort is not supported. Further, as noted above, Oppelt is directed to a coil that lies in a plane perpendicular to a main magnetic field, while Mehdizadeh *et al.*, is directed to a coil that lies in a plane parallel to the main magnetic field. Accordingly, the Office Action has not set forth a reasonable likelihood of success of such a combination.

In light of the foregoing, Applicant asserts that claims 15-20 are patentable over the prior art of record.

Serial No.: 09/991,761

Docket No.: PHUS017060US (PII 3340)

Amendment A

## Conclusion

Applicant submits that claims 1-20 distinguish patentably and non-obviously over the prior art of record and are in condition for allowance. An early indication of allowability is earnestly solicited.

If any extension of time is required relative to this Amendment A, Applicant hereby petitions for such extension. The authorization to charge deposit account 14-1270 for the fees associated therewith and for any other fees associated with this application, is hereby provided.

Respectfully submitted,

Thomas M. Lundin  
Reg. No. 48,979  
Phillips Intellectual Property and Standards  
595 Miner Road  
Cleveland, Ohio 44143  
T: 440-483-4281  
F: 440-483-4874

25285.1